INDUSTRIAL CHEMISTRY IN SPACE*≠

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ABSTRACT

Chemical manufacture relates to a space environment as it relates to air-free chemical preparation. For example, oxygen-free copper would be a premium product.

I. INTRODUCTION

The usefulness of space ships as chemical factories rests on two points: (1) the elimination of the need for a container and the attendant possibilities of contamination and (2) the elimination of air.

Metallurgists are well aware of the contaminating effects of crucibles and it seems very likely that air has similar serious deleterious effects on the properties of many solid products. It seems likely also that the growth of crystals such as diamond from carbon vapor is seriously retarded by monolayer impurity films from these sources.

Therefore, we suggest that the possible merits of chemical manufacture in orbit outside the atmosphere be examined.

II. ORBITAL CHEMISTRY TECHNIQUES

A. DISTILLATION

Two heat sources--sunlight and radio frequency inductive heating--are

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available so distillation onto surrounding metallic collector baffles possessing blackened rear surfaces to facilitate radiative cooling appears to be possible. Since rf power carries a heavy weight penalty, every effort should be made to use sunlight.

At our distance from the sun 2 calories per minute fall on each square centimeter of surface normal to the solar direction so a parabolic mirror 100 meters in diameter might be able to deliver about eleven megawatts at its focal point perhaps a hot spot area of 100 square centimeters for a 110 kilowatt per square centimeter influx could be intersected. Such a heat source would evaporate a metal like copper at something approaching twenty five pounds per second! (Heat of vaporization taken as 60 kilocalories per mole.) For carbon (170 kcal/mole) the rates would be less but one sees that in principle tons of material could be processed per day.

Weightlessness makes both the deployment of the mirrored parabolic surface (presumably aluminized mylar similar to that used in the Echo satellites) and the feeding of material to the evaporator feasible. Figures 1a and 1b present schemes. Some problems exist in the design and deployment of the collector baffles but they appear to be manageable.

In the first design (Figure 1a) the two megawatts of sunlight is restricted to a 60° cone and thus can enter a rather narrow evaporator port possibly about as shown in Figure 2. The tungsten baffles constitute an open house with many spaces for gas escape but allowing no escape of the vapor to a slight extent through the light beam port.

Tungsten, with a melting point at 3410°C and a boiling point at 5927°C, should radiate the heat from the condensing vapor. Table I gives data for various candidate substances.

B. CRYSTAL GROWTH

The growth of crystals from a melt heated by the solar beam seems to be particularly straightforward. Due to the zero-gravity environment, perfectly homogeneous spherical single crystals of large size could be grown by seeding a slightly supercooled melt. By distilling away impurities which would serve as nucleating sites and making use of the high cooling rates possible in space, the manufacture of large amorphous spheres of normally crystalline materials also seems possible.

Also epitaxial growth on seed crystals from the vapor should result in near perfect superpure crystals.

C. PLASMA CLEANING OF SURFACES

Surfaces probably can be cleaned by alpha particle (helium ions) bombardment or by hydrogen plasma. Thus a 1 curie polonium source ($2.2 \cdot 10^{12}$/min.) should remove a monolayer of oxide from 1 cm^2 in about 1 hour exposure in the space vacuum. This technique probably would be more practical than supplying radio frequency power to generate beams of helium and/or hydrogen plasma.

D. DEAERATION BY BAKING IN SPACE

There is a distinct possibility that heating of a finely powdered solid or a liquid in the space vacuum, if accompanied by proper stirring, will accomplish a degassing of air adequate to essentially remove it.

E. WELDING AND JOINING

It would seem to be obvious that contact pressure welding should be infallibly effective in a spacecraft.

III. CONCLUSIONS

The possibilities of industrial chemical production of impurity sensitive materials is intriguing to say the least. At this time more actual evidence of the advantages of air-free and container-free production need demonstration.

We have some examples which are dramatic and convincing. Oxygen-free high conductivity copper in making vacuum circuit breakers practical serves as a good case. It has also been established that beryllium can be made ductile by vacuum distillation or zone refining.

It is our hope that crystal growth will be substantially facilitated by the removal of the inhibiting effects of air. Our main goal in this area is large sized diamond grown from carbon vapor.

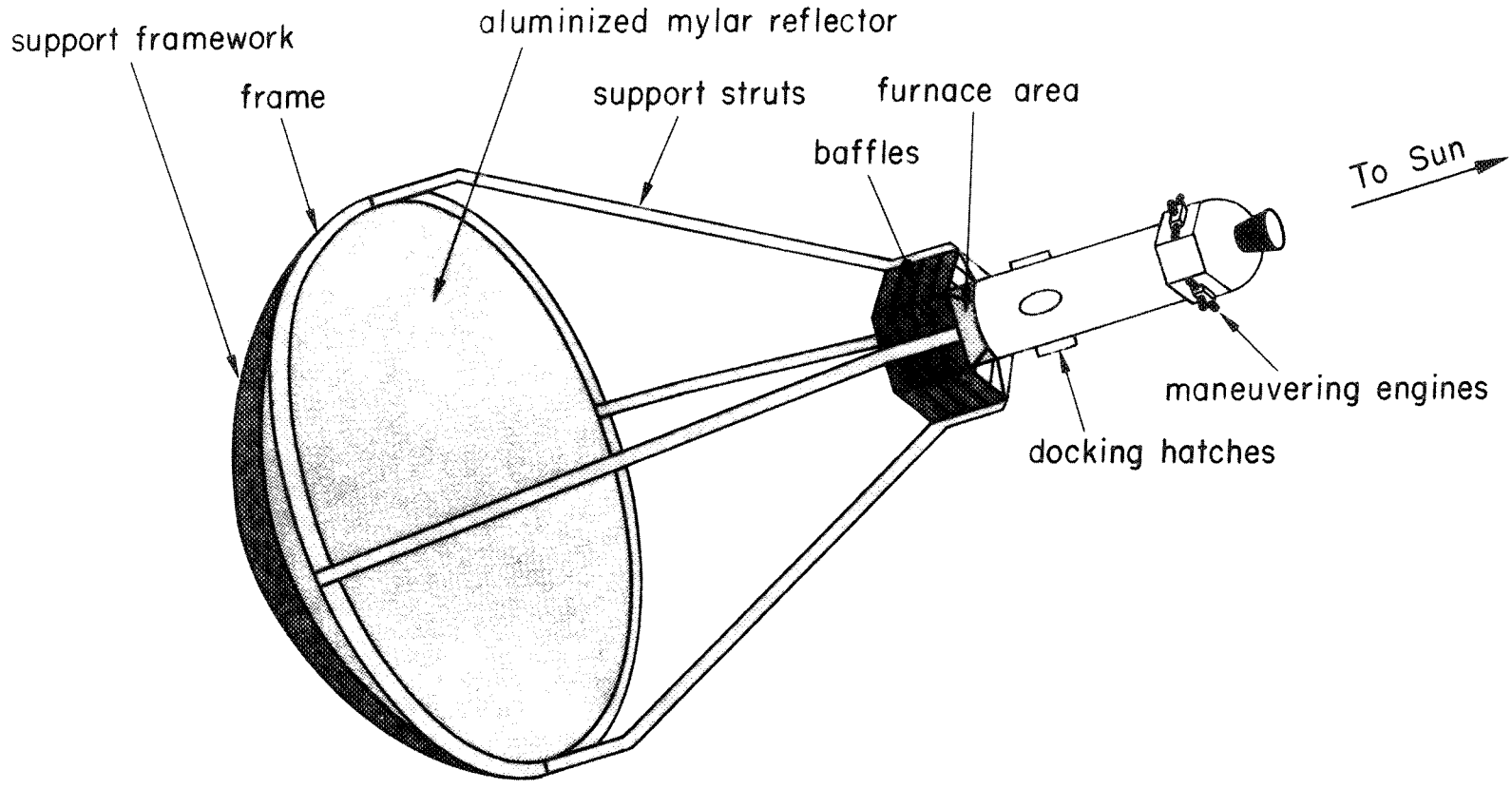

Figure 1(a). Orbiting Solar Furnace

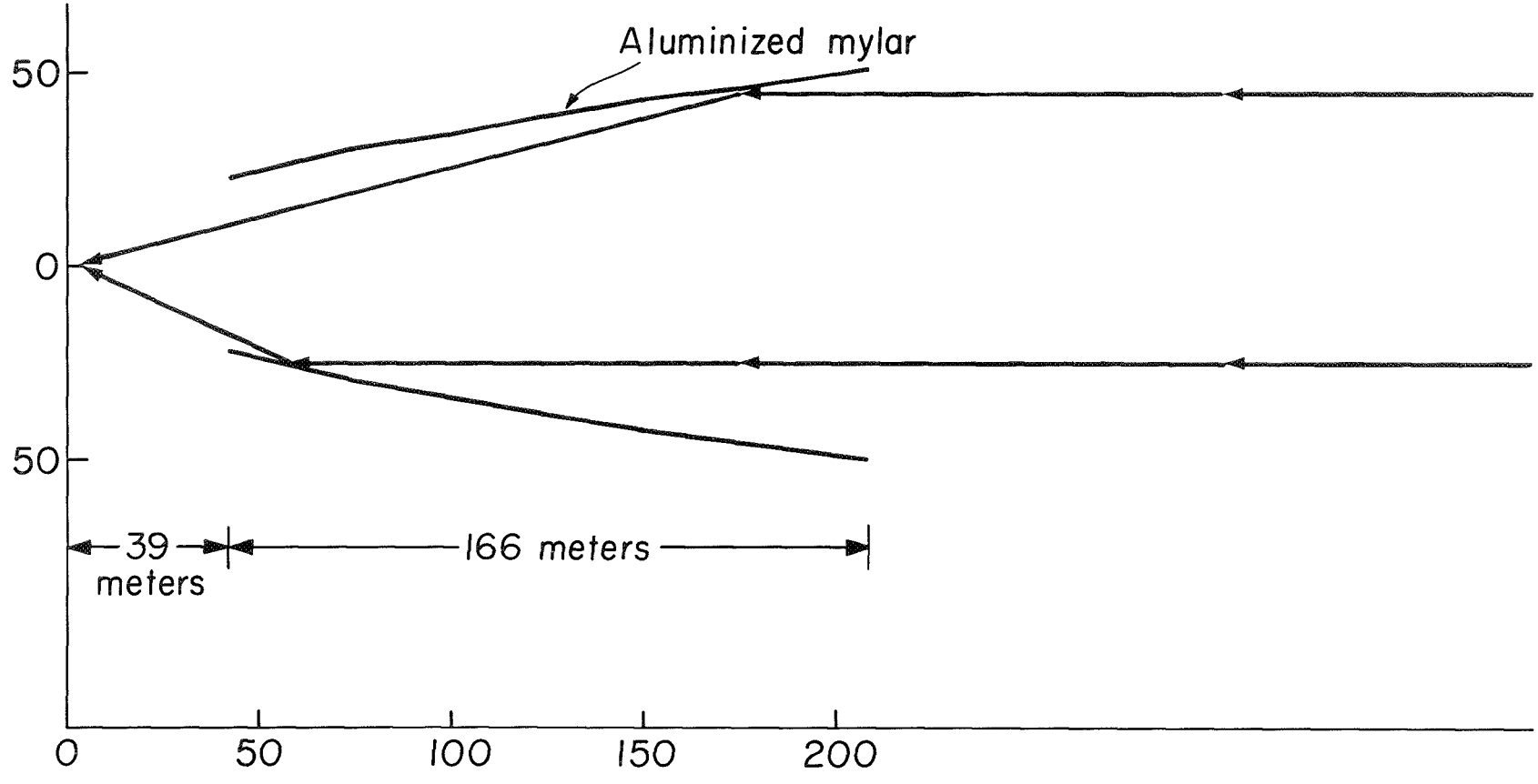

Figure 1(b). 2 Megawatt Solar Furnace for Space Chemical Plant

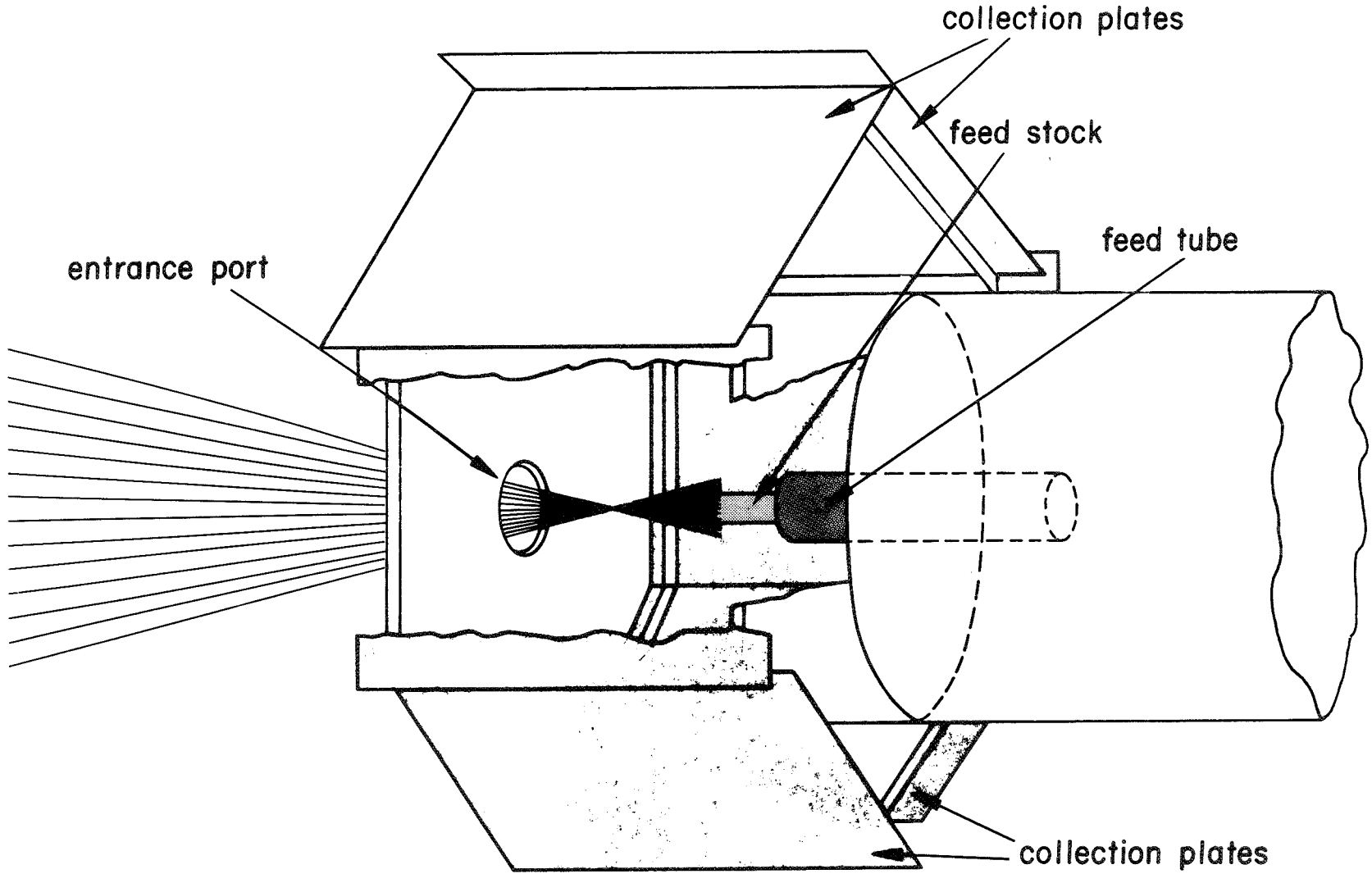

Figure 2(a). Evaporation Area of Solar Furnace (external support network not shown)

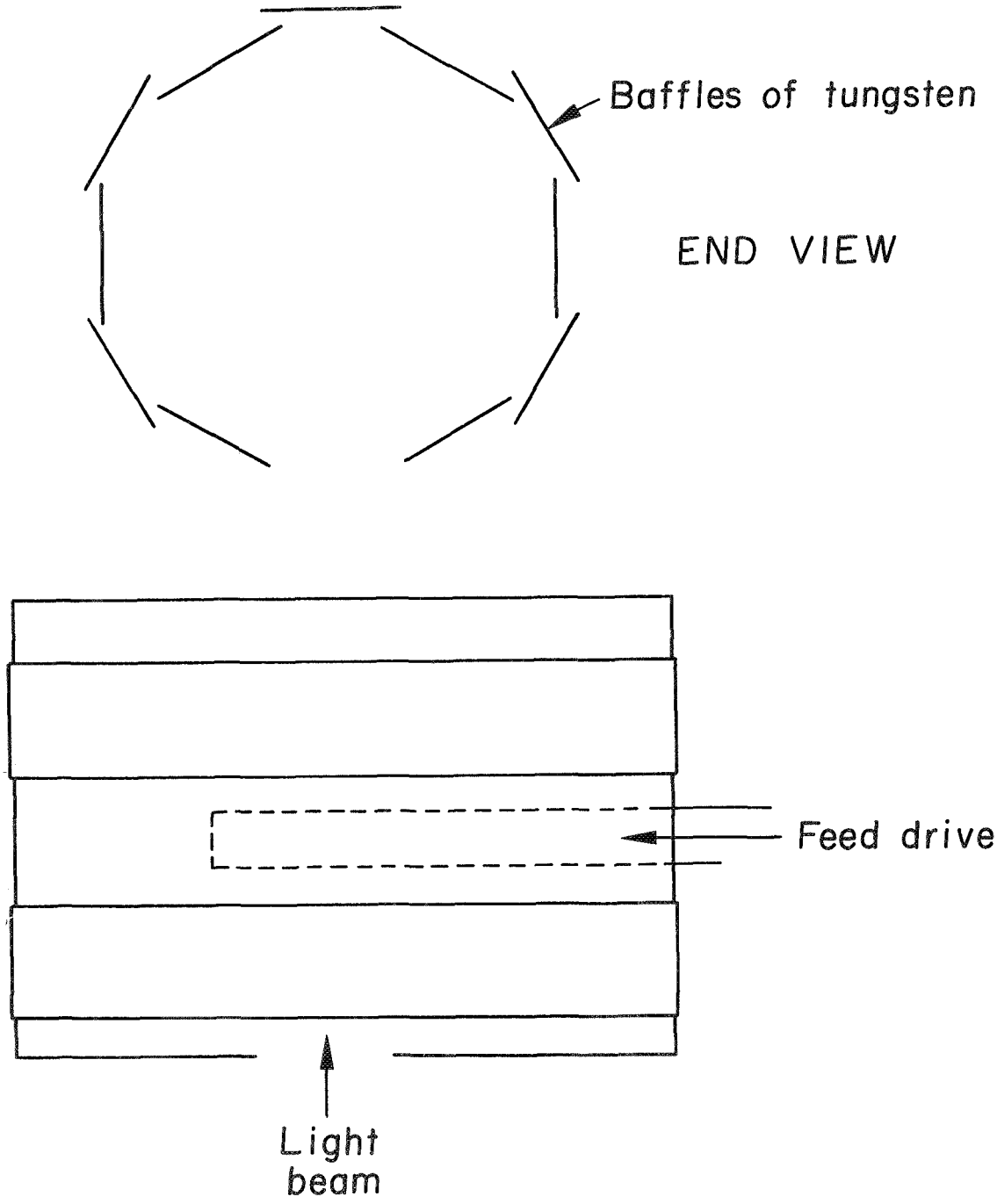

Figure 2(b). Evaporator